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ABSTRACT

What is the status of our present knowledge concerning the influence of malnutrition on intellectual development, learning, and behavior in children? This paper focuses primarily on an identification of some of the major issues and questions which are of concern to investigators in the field. The major concern of this review is with undernutrition, or malnutrition produced essentially by an insufficiency of protein and calories in the child's diet, commonly referred to as "protein-calorie malnutrition," which is regarded by many as the most serious nutritional problem on a world wide basis. Some consideration is also given to recent research on specific nutritional deficiencies and intellectual development. Several groups of studies are reviewed: (1) studies of protein-calorie malnutrition severe enough to markedly curtail physical growth, and to require hospitalization in the first several years of life; (2) studies of children having experience of more moderate, chronic malnutrition, judged usually on the basis of restricted physical growth; (3) studies of current efforts to evaluate the effects of various types of experimental intervention aimed at preventing or remedying the adverse consequences of malnutrition; and, (4) studies of relationships between intellectual functioning and specific deficiencies in such nutrients as iron or vitamins. (Author/JM)

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Malnutrition and Psychological Development[1]

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During the past six years or so, psychologists have become increasingly interested in the problem of nutritional influences on behavior and psychological development, with particular reference to the question of whether nutritional deprivation early in life impairs the development of intellectual, social, and motivational competencies in children. This growing interest developed in part as a consequence of the heightened social concern with malnutrition as a major public health problem in developing countries in Latin America, Africa, and Asia, and more recently, in parts of the United States as well. At the same time, as a scientific question, the influence of nutritional deprivation on behavioral development represents an issue of considerable importance for those investigators concerned with the broader problem of the interaction of biological, experiential, and social influences on early development, in both human and infrahuman species.

A substantial body of evidence has been accumulating for some time now, indicating that children's health, physical growth, and biological development may be seriously and even permanently impaired by the combination of severe malnutrition, infection, and parasitic disease which are endemic in many regions of the world where conditions of extreme poverty

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prevail (32, 36). Public concern about malnutrition as a social problem, both in this country and elsewhere, has been accentuated considerably by the more recent but growing view that malnutrition early in life is not only a serious threat to children's health and physical development, but may also have adverse effects on the development of intellectual functions, social competence, and adaptive behavior generally. By the mid 1960's, as this point of view was becoming quite prominent, it was based primarily on the following factors: growing evidence concerning reduced brain size and number of brain cells in seriously malnourished children (40, 41); animal studies indicating similar brain changes in early malnutrition, along with some impairment of performance in learning situations (1, 14); clinical observations by pediatricians of psychological changes as well as pronounced motor retardation in children with protein-calorie malnutrition (17); and early reports of malnourished infants and children with markedly reduced developmental quotients or IQ's on standardized tests (2,7,16).

During the period from approximately 1967 to 1969, when the White House Conference on Nutrition was held, and public concern with hunger and malnutrition in the United States was at a peak, there was a tendency in some circles at least to move rather prematurely from research findings indicating an association between malnutrition and impaired intellectual functioning, to somewhat oversimplified and in some instances rather exaggerated conclusions concerning a direct causal relationship between nutritional deprivation and mental retardation (33). Since that time, there has grown an increasing recognition of the fact that the relationships between nutritional deprivation and psychological development in

children are quite complicated ones, involving a variety of associated social, environmental, and biological factors, so that the problems are methodologically difficult to investigate, and are not yet clearly understood.

What is the status of our present knowledge concerning the influence of malnutrition on intellectual development, learning, and behavior in children? This paper focuses primarily on an identification of some of the major issues and questions which are of concern to investigators in the field, and, through a selective review of representative studies, an attempt is made to indicate some of the major conclusions suggested by the research done thus far.

Some Definitional Comments

The major concern of this review is with undernutrition, or malnutrition produced essentially by an insufficiency of protein and calories in the child's diet, commonly referred to as "protein-calorie malnutrition", which is regarded by many as the most serious nutritional problem on a world wide basis (19). Some consideration will also be given, however, to recent research on specific nutritional deficiencies and intellectual development.

Protein-calorie malnutrition includes the conditions of nutritional marasmus, or starvation, usually beginning in the earliest months of life and continuing for an extended period, producing infants whose physical growth and motor development are grossly impaired; and kwashiorkor, due primarily to an insufficiency of protein, typically occurring as a rather acute illness toward the end of the first year or in the second year of life, frequently after the birth of a younger sibling. Many combinations

or mixtures of these two conditions are found in practice, and they vary greatly in severity and duration (35).

One of the important methodological problems in this area is that it is difficult to secure accurate assessments of nutritional status in children, particularly if one is concerned with measurement throughout a broad range of nutritional variation, and not simply with clinically obvious and severe malnutrition. Three types of measures are usually employed: assessment of food intake from detailed dietary information; clinical or physical evaluations, including various anthropometric measures, particularly height, weight, and head circumference; and biochemical evaluations of specific nutrients from blood and urine samples. The interpretation of such measures is considered quite difficult, particularly if one attempts to judge the adequacy of an individual's nutritional status from a single index, and many nutritionists feel that these assessments are most valid when used in combination with one another (39).

A final definitional comment has to do with the importance of distinguishing between hunger and malnutrition. The school child who frequently misses breakfast or lunch may perform poorly because of inattentiveness and distractability associated with hunger. However, these potential influences on school performance and learning, about which we know very little, clearly need to be differentiated from those effects which are the result of long term protein-calorie malnutrition. Many severely malnourished children are characterized by apathy, withdrawal, and loss of appetite, rather than by the increased activity and restlessness associated with hunger (11).

Major Questions and Research Strategies

The specific research questions which are of major concern to investigators in this field may be summarized as follows:

1. Does malnutrition adversely influence learning, behavior and psychological development in children? How severe are these effects? Are they reversible with nutritional rehabilitation, or through the provision of enriched experience and stimulation?

2. How do the effects of malnutrition vary as a function of severity, age of onset, duration, and the particular type of malnutrition involved?

3. Can the influence of malnutrition as such be isolated from the associated effects of those social, environmental, and biological conditions typically involved in the ecology of human malnutrition? Perhaps more importantly, how do such conditions interact with malnutrition in jointly influencing psychological development?

4. Can we identify the particular behaviors and psychological processes which are most sensitive, and those which are least sensitive to nutritional deprivation?

5. Finally, how are the behavioral effects of malnutrition mediated--for example, through brain changes leading to impaired ability to learn even under conditions of appropriate motivation and responsiveness, or through dysfunctional changes in arousal thresholds or responsiveness to the environment?

Given these major questions, let us briefly consider some of the principal research strategies that have been employed by investigators in attempting to deal with them. Most studies of protein-calorie malnutrition and psychological development have been based on samples of

children from poor populations in Latin America, Asia, and Africa. A majority of them have involved the behavioral assessment of infants and children with a known or presumed history of malnutrition, whose performance is compared against some sort of standard, or control group. Some of these investigations have dealt with protein-calorie malnutrition severe enough to require hospitalization and treatment some time in the first two or three years of life. Others have focused on children who presumably have been exposed to more moderate, chronic malnutrition, usually judged on the basis of restricted growth in stature and/or brain circumference.

The second major research strategy, employed increasingly in recent years, involves an essentially longitudinal approach, with major emphasis on the effects of various types of experimental intervention. Groups of children in situations where chronic malnutrition is endemic are provided with nutritional supplementation and improved medical care, and an evaluation is made of the behavioral consequences, as well as the nutritional and growth effects. More recently, we are beginning to see environmental stimulation included as an additional intervention.

A third approach, also longitudinal and considerably less common than those already mentioned, involves ecologically oriented, relatively detailed studies of the growth and development of samples of children from birth, in settings where a good many children are clearly at risk with regard to malnutrition. The assumption here is that because of natural variation in such a population, it will be possible to study prospectively, those conditions which lead to the development of malnutrition in some children and not in others in the same environment (10).

Studies of Severe Malnutrition

Let's consider first studies of protein-calorie malnutrition severe enough to markedly curtail physical growth, and to require hospitalization in the first several years of life. In general, these investigations have found early and severe malnutrition to be associated with substantially reduced levels of intellectual performance, even in the early preschool years.

One of the early and well-known studies of this kind was carried out in Mexico City in the early 1960's by Cravioto and Robles (13). Twenty infants hospitalized for severe protein-calorie malnutrition were examined with the Gesell Infant Test every two weeks during treatment, which lasted as long as six months for some children. All infants were well below age norms on the Gesell scale shortly after admission, with Developmental Quotients mainly below 60. Moreover, children who had been admitted for treatment between 15 and 42 months of age showed considerable improvement in Gesell performance during rehabilitation, whereas those admitted between three and six months of age, whose weight retardation seemed more severe, showed virtually no recovery of their developmental deficit during the period of nutritional rehabilitation.

In a similar study conducted more recently in Beirut, Yaktin and McLaren (42) administered the Griffiths Mental Development Scale every two weeks to a sample of hospitalized infants during a four-month period of treatment for severe marasmus. At the time of hospitalization, when the children were between two and one half and 16 months of age, their average developmental quotient was approximately 50. During treatment

there was a steady improvement in the DQ's, which reached the low 70's after the four months of rehabilitation. While half the children were cared for in an ordinary five-bed pediatric ward with the usual caretaking routines, the other half were provided with environmental and social stimulation through a more complex material environment and additional caretaking and play activities. The stimulated infants showed a slightly greater degree of improvement than the non-stimulated group, although this differential was not significant.

Several very recent studies of hospitalized malnourished children have utilized carefully matched, non-malnourished control groups, and have begun to examine nutritional consequences on specific cognitive or learning functions, as well as on developmental test performance. Chase and Martin (9), working in Colorado, studied 20 children who had been hospitalized for protein-calorie malnutrition before the age of one year. When these children were examined approximately three and one half years later with the Yale Revised Developmental Examination, those who had been admitted and treated some time during the first four months of life had essentially normal developmental quotients, equivalent to the control group mean of 99. On the other hand, the children who had been hospitalized and treated some time between four and 12 months of age had a significantly lower development quotient, with a mean of 70. The latter group, which presumably had been malnourished for a longer period of time without treatment, was also more retarded in physical growth, both at the time of hospitalization and on follow-up three and a half years later. It should be mentioned that the infants in this investigation, who were hospitalized for 16 days on the average, were not as severely

malnourished as most infants included in the previously mentioned studies from Latin America and Lebanon.

While the aforementioned study involved a careful matching of malnourished and control subjects on social, family, and environmental factors, the authors point out the great difficulty of separating undernutrition from the influence of these associated environmental factors. This caution is based on the fact that despite the careful matching, there was a higher incidence of social problems and stress in the homes of the malnourished children, whose mothers also had significantly lower scores on an index of home stimulation.

A carefully controlled study still underway in Chile, conducted by Kardonsky, et al (20) also provides evidence of reduced intellectual functioning in preschool children hospitalized for severe malnutrition in the first year of life. At about three to four years of age, these children had a mean IQ of 73, although when reexamined two years later, there was a considerable improvement in their intellectual functioning. Moreover, children whose malnutrition occurred earlier, as judged by weight deficit, and whose recovery was more rapid, tended to have less marked IQ deficits, a finding consistent with those of Chase and Martin. In a series of other tests of specific psychological functions, the Santiago group are finding that malnourished children show increased excitability and reduced exploratory behavior, results consistent with recent behavioral studies with pigs, rats, and rhesus monkeys (25).

Another investigation of specific cognitive functioning in severely malnourished children was done by Brockman and Ricciuti (6), working with children from 12 to 43 months of age who had been hospitalized for

severe marasmus in Lima, Peru sometime between two and a half and 42 months of age. Using simple sorting tasks to assess categorizing behavior, it was found that the malnourished children performed substantially and significantly less well than a control group selected from the same population on the basis of their greater height. Moreover, children with a longer period of nutritional treatment, with greater gains in body length and head circumference during treatment, and with high medical ratings of nutritional recovery, tended to perform better on the cognitive tasks.

Several studies in Mexico (12), India (8) and Jamaica (18) provide evidence that even school-age children hospitalized for severe malnutrition during the first two to three years of life perform less well than carefully matched control children without such a history. For the most part, however, the investigators themselves caution that while early malnutrition may well be implicated as an important determinant of the differences reported, the same environmental and social factors which contributed to the development of malnutrition in some children and not in others in the same environment, may also contribute directly to the observed reduction in intellectual performance.

Generally speaking, then, there is reasonably good evidence that severe protein-calorie malnutrition in the first year of life may have adverse effects on intellectual development in children. The more severe the nutritional deprivation, and the longer it continues without rehabilitation, the greater the likelihood of substantial intellectual impairment, in some instances persisting into the early school years. On the other hand, if nutritional treatment and rehabilitation occur early in the first

year, the chances of recovery of normal or near normal intellectual functioning appear very good. Although the data are not entirely clear, it appears as though severe malnutrition beginning in the second or third years of life, produces effects which are less marked and more amenable to rehabilitation. In both instances however, it is not yet entirely clear whether postnatal malnutrition as such is the primary determinant of impaired intellectual functioning, or how it may interact with socio-environmental influences in producing such effects.

Moderate Malnutrition

There have been a number of studies of children having experienced more moderate, chronic malnutrition, judged usually on the basis of restricted physical growth, particularly in height, weight or head circumference. While these children often manifest reduced levels of intellectual functioning, one cannot attribute these effects directly and solely to malnutrition. The problem is that differences in stature, which may well reflect differences in nutritional history, are also associated with a variety of other social characteristics of the environment, or biological characteristics of the individual, which are themselves capable of influencing intellectual development (15,30,31).

A frequently quoted study by Stoch and Smythe in South Africa provides a good example of these interpretive difficulties (37). A small group of children between one and three years of age, who showed markedly reduced height, weight and head circumference, were followed over an 11 year period with periodic assessments of physical and intellectual develop-

ment. These undernourished children scored consistently lower than a taller control group by 15 to 20 IQ points on various intelligence scales, and their educational placement was considerably behind average. However, since the control children came from more stable homes with markedly better living conditions, and were attending an all day nursery school when the study began, it is impossible to determine to what extent the observed performance differences were attributable to malnutrition.

Several studies of tall and short school age children in Latin America raise similar interpretive problems. For example, in a Guatemalan village study of six-to-11 year old children (11), tall children tended to make fewer errors in identifying geometric forms on the basis of integrating visual, haptic, and kinesthetic information, particularly in the younger age groups. Although tall and short groups were generally equivalent in a number of socio-environmental background factors, maternal education was markedly higher in the case of the tall children, who may thus have had more opportunities for learning. In a more recent study of one to five year old children in Chile (27), a substantial correlation ($r=.71$) was found between mother's IQ and the children's growth in height. Thus, while mother's intellectual competence may well influence the adequacy of nutritional care she provides her children, it may at the same time account at least in part for observed differences in the children's intellectual functioning, through genetic influences, and/or through the social and learning environments available to the children.

Several recent investigations of moderate malnutrition in preschool children are of particular interest because they provide additional examples of the growing trend toward the assessment and analysis of specific

perceptual-cognitive, learning, and motivational functions which might be influenced by nutritional deprivation. One of the best illustrations of this approach may be found in some preliminary studies by Klein et al in Guatelmala (21), contrasting the performance of five-year-old children previously treated for malnutrition at a rehabilitation clinic, with the performance of taller control children from generally similar social backgrounds. The malnourished children performed more poorly than controls on two tests of short term memory and two perceptual discrimination tasks, all of which placed a high premium on sustained attention. On the other hand, the groups did not differ on 11 other tests, including measures of simple recall, vocabulary, visual-haptic matching, simple discrimination learning, and exploratory behavior. A careful analysis of their results suggested to Klein and his colleagues that the performance differences observed in these children reflect primarily differences in attention and task concentration, rather than differences in perceptual-cognitive or memory capacity as such. This general view is compatible with other recent observations of malnourished preschool children in Colombia (23), and also with recent animal work (25).

With respect to the influence of moderate protein-calorie malnutrition, then, research thus far suggests that effects on psychological development are much less pronounced and consistent than is the case for severe and early malnutrition. Moreover, the particular contribution of nutritional factors, relative to the role played by concomitant social and environmental influences, is not at all clear. At the same time there is growing evidence indicating that the major influence of malnutrition may be upon attentional, arousal, or motivational responses in

children, rather than upon basic cognitive or learning competencies.

Intervention Studies

Of increasing importance, from the point of view of both research and remediation, are the current efforts to evaluate the effects of various types of experimental intervention aimed at preventing or remedying the adverse consequences of malnutrition. For example, several rather elaborate studies of the long term effects of nutritional supplementation and improved health care on both the physical and psychological development of children at risk of malnutrition are presently underway in both Guatemala (22) and Colombia (23).

Some preliminary findings of considerable interest have been reported by the McKays in Colombia (26), concerned with the effects of both nutritional remediation and cognitive enrichment. Pre-school age children identified as having been moderately malnourished were provided with nutritional supplementation and added health care. One group had in addition a five month pre-school experience involving a program of cognitive stimulation as well as training in number and letter recognition skills. The pre-school program of cognitive stimulation increased the intellectual performance of the malnourished children to about the same level as that achieved by non-stimulated, taller controls from the same environment, but considerably below the level achieved by controls who had also been cognitively stimulated. Nutritional and health care alone, without stimulation, produced no greater improvement in performance over the five month period than that shown by several normal and malnourished groups receiving no treatment of either kind. As one might expect, the

greatest gains came from training on specific number and letter naming skills by both normal and malnourished children, who had virtually identical scores before and after training. Although this research has some methodological complications which make interpretation difficult, the results so far suggest that intellectual consequences of moderate malnutrition may be amenable to substantial remediation through nutritional supplementation and appropriate educational experiences, which may have a greater corrective impact than nutritional improvement and health care alone. Compatible with this view are the results of recent animal work suggesting that behavioral effects of early malnutrition can be greatly minimized or eliminated by additional stimulation early in life (24).

Specific Deficiencies

In the past few years, with the increase in broad scale surveys of nutritional deficiencies in disadvantaged populations in this country (39), a number of investigators have examined relationships between intellectual functioning and specific deficiencies in such nutrients as iron or vitamins. In some instances, the intellectual consequences of nutritional treatment of these deficiencies has also been investigated. In a recent survey of nutritional deficiencies in disadvantaged preschool children in Nashville, Tennessee, Sandstead et al (34) found no relationships between Stanford-Binet IQ and a variety of biochemical indices of nutritional status. It should be mentioned, however, that these were children with mild degrees of malnutrition (only five percent had hemoglobin values below 10.5 gm/100 ml.).

In a recent study by Beller and Howell (3), a variety of intellec-

tual and perceptual tests were given to nearly 100 four- to six-year-old children with mild to moderate iron deficiency anemia, who were enrolled in Philadelphia day care centers. No IQ differences were found between the anemic children and non-anemic controls from the same day care groups, a finding consistent with those of the Nashville study just mentioned. Moreover, relatively few differences were found between the two groups in the extensive battery of perceptual measures employed. Interestingly enough, these differences were in the areas of attention and task concentration, the same functions which appeared vulnerable to moderate nutritional deprivation in some of the previously mentioned studies. After two months of iron treatment administered to half the anemic children, there were essentially no clear changes in intellectual or perceptive functioning which could be attributed to the nutritional remediation. It should be noted, however, that the iron treatment also failed to produce a significant increase in hemoglobin level for the treatment as compared to the non-treatment anemic children.

In contrast to the two studies just mentioned, Sulzer et al (38) found that more severe iron deficiency anemia, when associated with growth retardation suggestive of longer term undernutrition, was related to reduced performance on several tests of intellectual functioning, including associative reaction time. No relationships were found with object sorting, short term memory, and syntactic memory, however.

On the basis of research done thus far, it does not appear that moderate deficiencies in specific nutrients such as iron or vitamin B 1 have very substantial or lasting effects on psychological functioning in children, in the absence of more pervasive malnutrition; nor will nutri-

tional supplementation with such specific nutrients alone produce appreciable changes in levels of performance. Whether more severe and prolonged dietary deficiencies in these nutrients might affect children's learning and intellectual development is not yet clear, and further research on the problem is certainly warranted.

In the interest of brevity, no attempt has been made to deal with the important topic of maternal and fetal nutrition. Suffice it to say that severe maternal malnutrition during pregnancy, and substantial deficiencies in the mother's previous nutritional and growth history, represent important contributing influences involved in the production of low birth weight, high risk infants whose subsequent psychological and behavioral development may be significantly impaired (4,28). It is extremely difficult, of course to isolate the influence of maternal nutritional deprivation as such from the many other complications and abnormalities of pregnancy, labor, and birth which may have substantial adverse effects on the child's development. Nevertheless, severe deficiencies in the mother's nutrition, growth, and health care during her previous life span as well as during pregnancy, increase substantially the risk of behavioral and mental subnormality in the infant and child (5,29).

Summary and Conclusions

Let me now try to summarize briefly the major points of this review, in the context of the main questions which were posed at the outset. Impairment of intellectual and psychological development in children as a consequence of protein-calorie malnutrition appears most likely to

occur and to be rather severe and long lasting, to the extent that nutritional deprivation begins in the first year, is very severe, and continues for an extended period of time without nutritional remediation. Extreme conditions of this sort are associated with borderline or more severe mental sub-normality, sometimes persisting into the pre-school and early school years. On the other hand, severe early malnutrition which is subject to adequate nutritional remediation within the first five or six months of life, appears relatively unlikely to reduce intellectual functioning below normal or near normal levels. In contrast with nutritional marasmus, which typically begins in the first year, the condition of kwashiorkor, with typical onset in the second year or later, seems to produce behavioral effects which are considerably less severe and more amenable to remediation. Psychological consequences of the mild to moderate malnutrition found in many socially disadvantaged populations are quite unclear, and appear to be rather slight and relatively reversible. Effects of moderate deficiencies in specific nutrients like iron or vitamins upon intellectual functioning seem even more questionable.

While severe malnutrition seems clearly implicated as one determinant of impaired intellectual development, it has been extremely difficult to isolate this influence from that of various social, educational, family, and child rearing conditions typically associated with malnutrition, and capable of exerting major influences on psychological development in their own right. It seems reasonable to infer that when malnutrition is severe, early, and enduring without treatment, it plays a substantial if not major role in shaping the course of subsequent psychological development, relative to the other conditions mentioned. On the other hand, it appears very

likely that mild or moderate malnutrition plays a relatively minor part in determining children's intellectual development, in comparison with the substantial influence of various social, environmental, and genetic factors.

It is not yet entirely clear what specific behavioral functions and psychological characteristics are most vulnerable to nutritional deprivation, and how such effects are mediated, although current research with both animals and humans is addressed increasingly to precisely these questions. Evidence from these studies suggests that malnutrition may exert its major influence on behavior through dysfunctional changes in attention, responsiveness, motivation, and emotionality, rather than through a more direct impairment of basic learning and cognitive competencies. It is also well recognized that some behavioral effects of severe malnutrition may be very indirect, brought about by changes in the way parents or other caregivers respond to and interact with the severely malnourished child.

The comments just made have clear implications with regard to the broad question of reversibility and remediation. Most of the evidence suggesting long term intellectual impairment in the case of severe malnutrition is based on studies in which remediation was directed primarily at the nutritional and health needs of the children, and not at the social environment which contributed to the development of malnutrition and lower levels of intellectual functioning in the first place. It is in this environment that the severely malnourished children's IQ's fail to show substantial improvement, although some gains do occur. Programs of remediation which provide an enrichment of the child's social and learning

environment in day care, school, home, and community settings, along with continuing nutritional and health care, may well reveal that the psychological and behavioral effects of even rather severe malnutrition may be amenable to substantial long term remediation and prevention. Programs of this sort are obviously of the highest priority from the point of view of human welfare and social action; they also represent the most fruitful research approach to the question of long term behavioral consequences of protein-calorie malnutrition.

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